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DWARFMISTLETOES

OF THE INTERMOUNTAIN AND NORTHERN ROCKY MOUNTAIN REGIONS AND SUGGESTIONS FOR CONTROL

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COVER PHOTO: Male shoot of Douglas-fir dwarfmistletoe with staminate flowers (enlarged).

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INTRODUCTION

Dwarfmistletoes cause the greatest single growth impact (mortality plus growth loss) to commercial tree species in the Northern Rocky Mountain Region according to the best available estimates. In the Intermountain Region the losses in coniferous stands charged to these parasites rank next to those from heart rots. The full impact of dwarfmistletoes on the productive capacity of coniferous stands has not yet been definitely determined, even though the general prevalence of these pests and the damage they cause were recognized more than 40 years ago (8).[1/] Reduction of losses from dwarfmistletoe is now considered the most important problem in forest disease control in these two regions.

Some valuable information on the proper treatment of affected forests has been gained in recent years. However, more research both basic and applied is needed for a thorough understanding of these parasites and their control.

This paper has been prepared primarily for the use of forest managers in the Intermountain and Northern Rocky Mountain Regions who are faced with the immediate necessity for dwarfmistletoe control and cannot afford to wait for results of further research. It assembles and summarizes pertinent published information and presents other known facts that may be useful in planning control of the principal dwarfmistletoes in these regions. In the absence of certain experimental information on the dwarfmistletoes, use has been made of the accumulated observations of trained pathologists.

SPECIES AND DISTRIBUTION

The dwarfmistletoes are seed-bearing plants belonging to the genus *Arceuthobium*. They can live and thrive only as parasites on living conifers. No extensive areas of coniferous forests anywhere in the Northern Rocky Mountain or Intermountain Regions are completely free of one or more of the dwarfmistletoes. Four species, classified by anatomical characteristics, occur in these regions; one of them includes several forms which have different host preferences. Each species or form normally occurs on a single host tree. However, occasional departures from normal host trees do occur.

The five most important species or forms in the Northern Rocky Mountain and Intermountain Regions and their tree hosts and general distribution are:

1/ Underlined numbers in parentheses indicate numbered items in Literature Cited.

1. Lodgepole pine dwarfmistletoe: A. americanum (figs. 2, 7) is common on lodgepole pine throughout both regions. This pest is especially prevalent and damaging in eastern Montana, southern Idaho, and northeastern Utah; it commonly appears wherever lodgepole pine grows (3).

2. Douglas-fir dwarfmistletoe: A. douglasii (figs. 1A, 3) attacks Douglas-fir in both regions. In the Intermountain Region, distribution of this dwarfmistletoe practically coincides with the range of the host tree. It is especially abundant in southern Idaho and southern Utah. Many Douglas-fir stands in northeastern Washington, in the Nezperce National Forest in Idaho, and in the Bitterroot and Flathead valleys in western Montana are infected. This pest occurs in other local areas in northern Idaho and western Montana, but has not appeared in eastern Montana.

Figure 1.--Tree crowns infected with dwarfmistletoe: A, Mature Douglas-fir with most of the crown in a series of immense witches'- brooms. B, This western larch does not have a single normal branch; all are broomed and the top has died. C, This ponderosa pine, recently killed by dwarfmistletoes, shows the structure of brooms.

Figure 2.--Typical plants of the lodgepole pine dwarfmistletoe. The branch on the left bears a female plant with mature berries. The center and right-hand branches have male plants. Note the typical spindle-shaped swellings where shoots are attached.

3. Western dwarfmistletoe on ponderosa pine: A. campylopodum forma campylopodum (figs. 1C, 4) commonly grows on ponderosa pine in both regions, but has not been found in Montana. This dwarfmistletoe grows more abundantly in stands on the drier sites and along the outer fringes of the range of ponderosa pine in the Northern Rocky Mountain Region. This species of dwarfmistletoe also occurs in ponderosa pine stands in southern Idaho (6).

4. Larch form of western dwarfmistletoe: A. campylopodium forma laricis (figs. 1B, 9) grows on western larch and subalpine larch but is economically important only on western larch. This form is abundant and destructive throughout most of the natural range of western larch (7).

Figure 3.--Heavy concentrations of shoots of Douglas-fir dwarfmistletoe. Female shoots with berries above, and male shoots on lower branch. Shoots are usually scattered more sparsely among the host needles and are therefore usually less obvious.

5. Southwestern dwarfmistletoe: A. vaginatum is important on the Rocky Mountain form of ponderosa pine in the Intermountain Region (1). The range of this parasite does not overlap that of western dwarfmistletoe on ponderosa pine.

Several other forms of the A. campylopodum complex have some importance on grand fir, Engelmann spruce, subalpine fir, western hemlock, limber pine, bristlecone pine, pinyon, and singleleaf pinyon in a few local areas. Dwarfmistletoes occasionally occur on other conifers in the two regions (except junipers, western redcedar, and Pacific yew); however they are considered of little importance here.

DWARFMISTLETOE PLANTS

The various dwarfmistletoe plants are quite similar in general appearance, but they often vary between species and occasionally within species, in color, size, form, and in parts of their life history. These differences are sometimes barely evident, but at other times they are pronounced (2).

Aerial Shoots

Aerial parts of the parasites are leafless, delicate, segmented, perennial shoots (figs. 2, 3, 4) on the stems and branches of the host tree. The segments are four-sided at the base to angular or rounded above, and have a pair of minute scales (vestigial leaves) at the top. The color varies from yellow and purplish to brownish or olive green in many shades. Shoots of the Douglas-fir dwarfmistletoe (fig. 3) are smaller than those of any other local species, are seldom more than one-quarter to three-quarters inch in length, rarely branched, and are generally scattered along the young twigs of the host. Shoots of the other species more often occur in tufts (fig. 4); they are typically longer than 1 inch but seldom longer than 8 inches. The lodgepole pine dwarfmistletoe shoots (fig. 2) are more slender and stringy than those of the other species.

Seed Production

The male and female flowers are produced on separate plants, but both sexes may grow on the same host tree or even on the same branch. The Douglas-fir, lodgepole pine, and southwestern dwarfmistletoes bloom in the spring; those in the A. campylopodum complex in the late summer. The berries (figs. 2, 3, 4), containing a single seed, mature the second autumn after pollination. The berries ripen and seeds are disseminated in September or early October, except for A. vaginatum, which matures in late July or early August.

At maturity the berry develops an internal pressure which triggers an explosion and expels the seed forcibly into the air. The seeds, covered with a sticky substance called viscin, may glance off from objects near the point of explosion, but they usually fasten themselves wherever they hit.

Figure 4.--Typical plants of western dwarfmistletoe on ponderosa pine: A, female plant with mature berries; B, male plant.

Germination and Growth

Infection can occur most easily when the discharged seed adheres to the bark of 1- to 3-year-old twig growth on a susceptible host. However, older growth in ponderosa pine, lodgepole pine, and probably other species is sometimes susceptible to infection (3, 4). Germination may follow in a month or so in A. vaginatum but is probably delayed until spring in most species of dwarfmistletoe. The seed sprout grows along the bark or needle surface (fig. 5); if it reaches a suitable obstruction, a padlike holdfast forms at its tip. From this a primary haustorium develops and penetrates the tender bark; from there an absorption system is established inside the bark tissue of the host.

Figure 5.--A germinated seed of the Douglas-fir dwarfmistletoe fastened at the base of needles on a young twig of Douglas-fir. Note the seed sprout obstructed by the base of a needle, where a holdfast is forming, and from which a primary haustorium will develop that will penetrate the thin bark of the twig. (Photo by C. W. Waters.)

(fig. 6). The parasite cannot penetrate wood tissue. The absorbing system consists of threadlike strands in the inner bark and wedge-shaped structures called sinkers, which become imbedded in the wood by the formation and growth of wood tissue around them. The sinkers maintain contact with the strands in the bark and provide them with water and dissolved materials from the sapwood. The strands produce buds that push through the host bark (fig. 6C) to form the aerial shoots.

A single infection may produce a large absorbing network in the host tissue from which many crops of aerial shoots arise (fig. 6). The absorbing system advances in distal, proximal, and tangential directions. Distal rate may be faster in some species like A. douglassii. This absorbing system may become systemic in character and live for many years without producing aerial parts of the parasite.

The life cycle of the dwarfmistletoes from seed germination and infection to seed production undoubtedly varies between and within species. After infection by A. vaginatum, at least 2 years--usually 4 or more--elapse before the first aerial shoots are produced. Generally the life cycle of this species requires 5 years or longer (1). The complete life cycle of other dwarfmistletoe species is unknown but is probably similar to that of A. vaginatum.

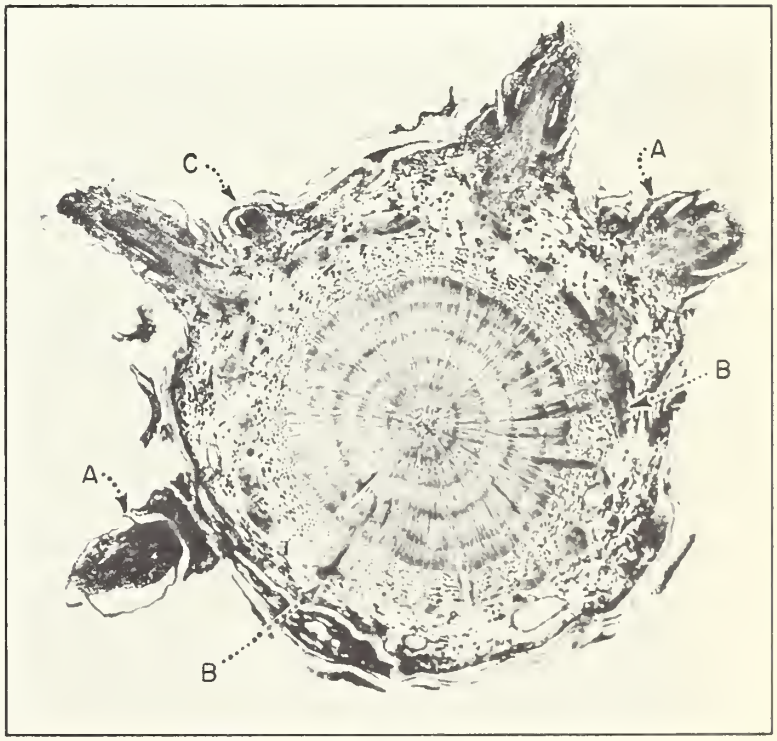

Figure 6.--Enlarged cross section of lodgepole pine branch infected with dwarfmistletoes: A, Basal cup on bark surface with portion of aerial shoot attached. B, Absorbing strands of the dwarfmistletoe plant in the inner bark from which shoots arise, and from which the sinkers originate and extend into the wood. C, A new shoot bud breaking through the bark.

Means of Spread

Effective spread of these parasites results from the explosive force of the fruits. Because of the position of the berries, the seeds usually shoot upward and arch outward. By this means, new dwarfmistletoe plants continuously become established progressively higher in the crowns of infected trees. The degree of infection in an individual branch may be intensified by the advancement of the absorbing strands in the host tissues, as well as by seed dispersal.

Seeds that do not stick to the upper part of the host tree continue their flight outward and may infect surrounding trees within range. Spread to new trees is most effective where the seeds pass from overstory to understory. Most of the dwarfmistletoe seeds in an infected overstory tree are broadcast into the surrounding understory for a radius of 30 to 60 feet. Probably the angle at which a seed is discharged is the most important factor that determines the distance of spread. The effects of size of seed, height of seed-producing plants, steepness of ground slope, intensity of wind, and vigor of the host tree on the distance of spread have never been accurately determined. Spread is probably at least twice as fast in stands of mixed size classes as in even-aged stands.

It is believed that stand origin and history over past centuries are the major factors responsible for the widespread occurrence and distribution of the dwarfmistletoes. Various agents, such as birds and mammals, presumably could carry seeds for long distances. The part that such agents play in the spread of the parasite is unknown but is believed to have only minor practical importance.

SYMPTOMS OF INFECTION

The surest indication of infection is the presence of the dwarfmistletoe shoots. If shoots have dropped off, the small basal "cups" from which they came often remain on the bark (fig. 6). Infected stands or trees (figs. 1, 7, 8) are usually recognized by the accompanying witches'-brooms, spike-tops, cankers, swellings, and other abnormalities of trunk and branches.

Witches'-brooms.--Witches'-brooms, or malformed and swollen growths of twigs and branches in clumps (fig. 1), are striking symptoms of long-standing infection. Not all witches'-brooms are caused by dwarfmistletoes. Whenever the cause of brooming is questionable the broom should be examined for the presence of dwarfmistletoe shoots or basal cups. Brooming may be confined to a single limb, may occur on numerous limbs, or may include the entire crown. Typical brooms on lodgepole pine and Douglas-fir are practically spherical balls of dense growth, while those on larch radiate from a common point of origin. The typical brooms on ponderosa pine are spherical, but may not be very conspicuous because of the normal loose-branching habit of the host. Abnormally enlarged, swollen, or crooked branches usually occur even where brooms are inconspicuous.

Figure 7.--Mature stand of lodgepole pine breaking up from heavy infection of dwarfmistletoes. Note dead trees on the left and heavily infected tree in the center and far right background.

Cankers and Swellings.--Slight to definite, more or less fusiform swellings or cankers usually develop on infected twigs, branches, and stems (figs. 2, 4). When a branch infection extends into a larger branch or the bole, the infected branch is likely to be conically swollen; i.e., broadest at the base, with a marked taper. A cross section through a branch swelling generally shows the wedge-shaped sinkers extending into the wood (fig. 6).

Trunk symptoms of dwarfmistletoe attack are large, elongated, and flattened cankers on one or more sides of the trunk or spindle-shaped swellings that include the entire circumference of the tree. They result from persistent infection on the main stem that started early in the life of the tree. Trunk symptoms commonly appear on western larch (fig. 9), lodgepole pine, and ponderosa pine and occur occasionally on other species.

Other Symptoms.--The most severe infection usually develops first in the lower part of the tree crown. Dead tops often result when heavy brooming occurs in a large portion of the crown. Spiketops are almost a universal condition in heavily infected larch, Douglas-fir, and lodgepole pine stands. In the portions of the crown not broomed, reduction in foliage density and shortened and lighter colored needles result from the dwarfmistletoe infection.

Light to moderately infected stands are not readily distinguished from healthy ones except by the presence of such symptoms as brooms, cankers, and the dwarfmistletoe shoots. Heavily infected stands, on the other hand, show a ragged and degenerated condition (figs. 7, 8), similar to stands on a poor site. They contain deformed spike-topped, stunted or dying, and dead trees. Understory trees may have an abundance of dwarfmistletoe shoots with some evidence of branch malformation. Excessive mortality sometimes occurs in understory trees.

Figure 8.--Mature stand of Douglas-fir heavily infected and damaged by dwarfmistletoe.

DAMAGE

Dwarfmistletoe damage is extensive but not always spectacular in coniferous forests in the two regions. Trees of any age may be retarded, deformed, or killed. The general nature of dwarfmistletoe injury is a suppressing effect that is probably caused by gradual reduction of effective leaf surface of the tree, or by malfunction of the normal physiological processes of the tree, or both. Severely diseased stands result from a continuous intensification of the parasite over many years. As time passes, tree damage increases and wood productivity decreases.

Damage by dwarfmistletoes falls into the following four general categories:

1. Increased mortality.--Dwarfmistletoes do not usually kill rapidly in the sense that great numbers of larger trees may suddenly die, except in occasional severe drought years. Except for seedlings and young saplings that become infected, death due to the parasites usually results from gradual suppression. Nevertheless, infected merchantable trees do have a shorter life expectancy than healthy ones.

2. Growth reduction.--Dwarfmistletoes reduce tree vigor; this may cause a great reduction in height and diameter growth. Old mature trees, infected

Figure 9.--Trunk swelling and canker on a mature western larch caused by dwarfmistletoe infection. The witches'-brooms have long since disappeared.

for a long time, may be so stunted that they contain only one to three logs of low-quality and excessive taper, rather than the five to seven logs characteristic of healthy trees on the same site. Severely infected immature trees may never attain sawlog size. A reduction in the quantity of merchantable material results from trunk swellings and cankers (fig. 9), and from decay they may harbor, as well as from retarded growth. In infected Douglas-fir stands and to a lesser extent in other species, the ground is often heavily shaded by low, sprawling, and deformed trees. The space occupied by such trees is wholly wasted, and the opportunity for maximum yield from the site is lost.

3. Quality reduction.--Important losses occur from degrade or cull in lumber or logs. Numerous large knots and abnormally grained, spongy wood that is frequently pitchy, reduce quality. Fungi that cause stains and decay often enter open cankers and reduce quality of the wood.

4. Seed reduction.--Seed production and quality are reduced by dwarfmistletoe infection. Increased severity of infection results in a marked decrease in yield of cones and seeds per tree, and the percentage of seed germination. Resulting seedlings may be inferior to those produced by healthy trees.

In addition to these four major types of damage, heavy dwarfmistletoe infection predisposes trees to attack by bark beetles, wood decay and root disease, as well as windthrow and breakage. Large dwarfmistletoe brooms, especially the dead ones, are a fire hazard, and killed trees and spiketops constitute special fire hazard from lightning strikes.

Damage is often light in well stocked even-aged stands, and may be absent in timber stands that have originated from complete burns. Conversely,

moderate to severe damage usually occurs in stands that have been protected from fire for long periods or that were selectively cut in the past.

Surveys in the Northern Rocky Mountain Region to determine the distribution and abundance of dwarfmistletoes have shown that these parasites are more severe and widespread than had been previously realized.

CONTROL

Two satisfactory methods of dwarfmistletoe control are known. The "eradication method" consists of the removal of dwarfmistletoe infected trees or infected branches of trees by direct eradication operations or through silvicultural methods; or by a combination of both. The "stand manipulation method" consists of converting an infected stand to one consisting of tree species not susceptible to the dwarfmistletoes present in the area. Any infected stand, whether merchantable or immature, should be individually appraised to determine which control method is most sound.

Current research by forest pathologists and forest managers is aimed at developing and refining these two control methods, and at devising others.

Development of a chemical or antibiotic that will kill the parasites without injury to their host trees appears possible. If such a material is developed, or if some known chemical or antibiotic is determined to be adequate, its application may supplement but is not likely to replace silvicultural control in commercial timber stands.

Some bark-chewing rodents and certain parasitic insects and fungi occasionally reduce, to some degree, the abundance of dwarfmistletoe plants. However, the activity of these biological agents has never been found sufficiently effective to control the parasite.

Individual trees occasionally show resistance to dwarfmistletoe. Resistant planting stock could probably be genetically produced; however, such a project would require considerable time and cost.

Eradication Method

Control may be accomplished by cutting, poisoning, burning, or otherwise eliminating all infected trees, or by pruning infections from them (fig. 10). Any degree of dwarfmistletoe removal less than complete eradication will not give complete control. Partial reduction of the parasites may be desirable at times from the economic standpoint when everything is considered. However, it should be emphasized that control measures that do not reduce the accumulated seed source to an innocuous level or management that does not provide for constant attrition against the parasites could result in both wasted effort and increased dwarfmistletoe damage.

The original cost of eradication may be greater than the cost of some lesser degree of reduction, but the eventual cost in the long run will undoubtedly be greater for partial control because of need for recurrent control operations and the accumulated growth impact on the stand by the disease. As long as the parasites are present, the potential for severe damage exists, and control operations will remain a continuing periodic cost in management. On the other hand, if complete eradication is achieved, complete control will be attained indefinitely.

Direct Eradication

Direct eradication means operations designed solely for the purpose of dwarfmistletoe control. Some direct eradication of dwarfmistletoe infections by tree cutting or by pruning out infected tree branches is required to supplement many silvicultural control operations. Branch infections on young trees may be cut out successfully when they occur a foot or more from the bole; however, this safety margin varies and is somewhat less for small branches and for some host and parasite species. Pruned branches should be cut flush with the tree bole. Bole infections cannot be successfully cut out. In general, trees that have bole infections or branch infections within a foot of the bole must be cut, poisoned, or otherwise killed to eradicate the parasite.

Dwarfmistletoe infections on killed trees or pruned branches die almost immediately, and cannot reinfect living trees. However, control operations should be avoided during the dwarfmistletoe seed dispersal period, if possible, to prevent unnecessary spreading of the seed.

In high-use recreational areas or on certain administrative sites, where values warrant the extra cost, infections in large trees as well as small ones may be pruned out. If, in such areas, it is desirable to retain as many

Figure 10.--Dwarfmistletoe was controlled in this pole stand of ponderosa pine by eradicating the parasite. Dead trees (at right) were poisoned because infections could not be cut out. Pruning eradicated infections from center of tree.

trees and as much tree crown as possible, spread of the parasite may be reduced, and new infections prevented, by pruning out only the active infections that are producing female shoots, leaving any old inactive infections that are not producing shoots and active infections that produce only male parasite shoots. Except for their capacity to start new infections, however, all infections are equally able to damage the host trees. Even though large old brooms may not be producing female shoots, it is usually desirable to remove them to help restore the thrift of the host tree.

Since new dwarfmistletoe infections require several years to produce visible shoots, latent infections previously established will appear after control operations. These latent infections will become manifest for several years after the initial operation. Therefore, followup operations are necessary to detect and remove these infections before they produce berries. The number and frequency of followup treatments will depend on the dwarfmistletoe species and host tree involved and the management objectives of the area. A series of two or three cleanings spaced at 3- to 5-year intervals will probably reduce the parasite to an innocuous level in most stands. After this period, control areas may be checked over occasionally for missed infections and for new foci of the disease.

Silvicultural Control

To obtain maximum timber production will require control of dwarfmistletoe in many coniferous stands in both the Northern Rocky Mountain and Intermountain Regions.

Incorporation of dwarfmistletoe control with silvicultural practices is the most practical and economical way to combat these parasites in affected stands managed for commercial timber production. Obtaining and retaining new dwarfmistletoe-free stands, after harvest cuttings, is the most efficient control procedure. Control in affected young stands of premerchantable age is more difficult and costly, although sometimes desirable and economically practicable. Control in young stands, as in high-use administrative or recreational areas, may sometimes be of the direct type rather than through silvicultural cutting.

Control through silvicultural operations fundamentally consists of dwarfmistletoe eradication coupled with harvest or improvement cuttings, without pruning of infected branches or with a minimum of such direct eradication effort. Most silvicultural control will be conducted at the time of harvest cutting. With some types of harvest cutting, supplemental direct eradication must follow. The harvest cut should remove all infected overstory trees. In stands of mixed species this will require, at the most, cutting all overstory trees of one or two species. After the source of infection has been eliminated from the overstory, all infections must be eradicated from the pole-sized trees and smaller advanced reproduction by pruning out branch infections or by cutting or otherwise killing infected trees.

Stands of a single species, under heavy infection conditions, are best treated by clear cutting (fig. 11). Any advanced reproduction or other unmerchantable residual trees must then be sanitized by direct eradication, or

Figure 11.--Silvicultural control of dwarfmistletoe in lodgepole pine through clear cutting: A, Improper cutting for best control--advanced reproduction and cull trees left standing, and narrow strips of border trees (right background) left protruding into clear-cut area; both are unnecessary sources of infection for new stand, now 7 years old. B, Proper cutting for best control--all advanced reproduction and cull trees cut, and border is smooth line. Such cutting insures infection-free reproduction, except in a narrow strip along minimum border stand.

killed by bulldozing or broadcast burning. Clear-cut areas should be as large and compact as practicable (fig. 11). Clear-cut areas that are broadcast burned and regenerated by seed from the slash or by planting can be large. The shape will usually depend on the existence of natural openings or disease-free areas that will serve as effective control boundaries.

Dwarfmistletoe control is practical on relatively small areas because of the limited distance of direct spread. Much can be accomplished to prevent spread of the parasite into sanitized stands by careful selection of the boundaries of control areas. Natural clearings, such as meadows, lakes, or streams are ideal control boundaries. Wide highways or other cleared rights-of-way may also serve as control borders. Such openings around control areas should be at least as wide as the tallest infected trees outside the control area to prevent spread into the sanitized area. Control boundaries should never pass through heavy infection centers.

When clear-cut areas are regenerated from bordering stands, any infected bordering stands must be cut within 10 years to prevent infection of nearby new reproduction. Likewise, to prevent infection of new reproduction around seed trees, infected seed trees must be removed within 10 years after the first seed crop from them.

In clear-cutting operations, as commonly employed in lodgepole pine stands, the most heavily infected stands should be given the highest priority for cutting.

If a clear-cut area requires planting, those portions that are near infected bordering stands should have planting delayed unless the border will be cut within a 10-year period. The alternative is to plant these strips to tree species not susceptible to the dwarfmistletoe present.

Recommended Procedure for Eradication Method

The following are general suggestions for steps in dwarfmistletoe control by the eradication method:

1. Select highest priority area for control.--Aside from other management objectives, highest priority control areas are those where dwarfmistletoe is doing the most damage, or where potential for damage is greatest. The most volume loss occurs where there is heavy mortality in old-growth stands. The greatest potential loss is in reproduction between 5 and 20 years old that is exposed to infected overstory residuals. Great potential loss also is found in small infection centers in large acreages of young stands otherwise free of the parasite. Occasionally large acreages of young trees, especially stands of fire origin, are free of the pest except for a few small infection centers. Such centers should be rendered dwarfmistletoe-free as soon as possible, while the job is small and the cost low, to protect the larger area indefinitely.

2. Delineate control area on the ground.--Include all infected trees in the control area when it is practical to do so. If infection is general and widespread, select control boundaries carefully so as to utilize natural disease-free boundaries wherever possible, and to avoid boundaries through heavy infection centers.

3. Eliminate overstory infections.--In merchantable stands with a younger understory, first eliminate all sources of overhead infection by removing all merchantable infected trees in the overstory. Unmerchantable overstory trees that are infected should then be killed, or all infections pruned from them.

4. Eradicate infections in the understory.--The understory stand should be sanitized by direct eradication of infection. Dwarfmistletoe growth and development is stimulated by added light. Removal of all or a large part of an overstory causes suppressed infections in the understory to flourish and intensify if not removed.

5. Periodically check the control area.--As previously explained under "Direct Eradication," the control area needs periodic examinations for detection of latent infections. These infections should be removed before their new shoots produce seed.

6. Protect new reproduction.--In clear-cutting operations, areas of infection should be "clean cut" (fig. 11B) or otherwise sanitized by dwarfmistletoe eradication. To protect new reproduction from infection do not expose the cut area to infected bordering stands or infected seed trees more than 9 years.

Dwarfmistletoe control in immature stands often may be incorporated in thinning and crop tree pruning operations. In such operations, it should be remembered that dwarfmistletoe activity is intensified by added light. In even-aged young stands most infections occur in the lower crown; thus many infected trees may be sanitized by pruning. It is advisable always to prune at least one branch whorl above the highest branch infection found. This will eliminate a large percentage of the latent infections that are not yet apparent. The best time for such control is after midsummer when the maximum number of young shoots can be detected.

Stand Manipulation Method

Manipulation of tree species for the control of dwarfmistletoe is sometimes possible because the dwarfmistletoes are host specific. Stand manipulation is best suited to mixed stands having one or more commercial tree species that are not susceptible to the dwarfmistletoes present in the area. However, on certain sites pure stands of an infected species may be converted by planting the area to a tree species that is not susceptible to the local dwarfmistletoe.

Harvest cuttings in infected stands of mixed species should be so designed that the area will become naturally regenerated with one or more tree species not susceptible to the dwarfmistletoes present.

No direct dwarfmistletoe eradication is needed when this control method is used. However, it may be desirable at times to release advanced reproduction of the favored species by cutting out competing trees of the susceptible species, whether or not they are infected.

CONTROL COSTS

Costs of control measures vary with the method or type of control, the intensity of dwarfmistletoe infection, the age and composition of the stand, and the size of the infected areas involved.

Silvicultural control in conjunction with harvest cuttings is the more economical type of control, and it is most economical when the harvest cut is a clear-cutting operation.

When harvest cuttings other than clear cutting are made, control costs will depend largely upon the amount of dwarfmistletoe infection remaining after the harvest cut.

Unit area costs will always be less in lightly infected stands than in heavily infected stands, except when clear cuttings are made.

To keep costs at a minimum, clear-cut units exposed to outside reinfection should have a low ratio of perimeter to area. Large areas approaching a circle or square are the most economical in widespread infections. Cutting of narrow strips should be avoided to keep reinfestation of the sanitized area from the uncut perimeter to a minimum, unless bordering infected stands will be cut within 10 years.

Any cost added to an operation because of dwarfmistletoe control, may be considered part of the control costs. For example, planting may be considered part of control costs where it becomes necessary because of altering procedures to effect dwarfmistletoe control.

Little control of dwarfmistletoe has been carried on in the Northern Rocky Mountain and Intermountain Regions; consequently, few actual cost figures are available. Forest managers are urged to keep cost records on all their dwarfmistletoe control operations so that cost data may be accumulated for conditions in these regions.

Control in ponderosa pine in the Southwest on 16,000 acres cost $4.17 per acre in 1953 to 1956, inclusive (5). This did not include the followup cleanings. A second recleaning operation on 1,052 acres of uncut all-aged ponderosa pine in Bryce Canyon National Park in 1959 cost $4.18 per acre.

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